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Development of Regression Models for Household Trip Generation (Case Study, Freetown Centre One)

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ABSTRACT : *Freetown, as the capital city of Sierra Leone has important roles in various sectors that require good provision of public transportation system. This research attempts to develop household trip generation models using Freetown Centre I district as our case study. The models are built by using multiple linear regression analysis, which establishes relationship between trip number and household socioeconomic attributes. Household interviews were used through the administration of questionnaires for data collection on household socio-economic and trip characteristics of the study area. The results were then analyzed quantitatively using Statistical Package for Social Sciences (SPSS 16.0 version). Mathematical models were developed and the results show that trip generation rate is highly dependent on the income status of the people in Freetown Centre I district. Model validation and optimization were done to test the usefulness of the proposed models. These results confirm that the proposed models can be used to forecast future trip number for the study area and areas with similar household socioeconomic attributes. It is recommended that due to the rapid growth of automobile ownership, especially motorcycle, new transportation planning should be done in order to create reliable and sustainable public transport system.*

KEY WORDS: *Transportation Planning, Household Trip Generation, Public Transport System*

I. INTRODUCTION

Transportation is a basic human need and a non separable part of any society. It shows a very close relation to the style of life, the range and location of activities and the goods and services which will be available for consumption. Freetown the capital city of Sierra Leone, has important roles in various sectors such as education, tourism, administration centre and commerce that require a good provision of *transportation system*. In 2006 the number of population that settled in Freetown was approximately 1,070,200 people. This population growth is predicted to increase every year that makes the provision of good and reliable public transportation become a vital part to support the population activities. The city's transport sector has been adversely affected by the rapid urbanization and the economic development of the country. Now-a-days *traffic congestion* is an issue of great concern for the inhabitants of Freetown resulting in *commuter's* frustration, longer *travel times*, lost productivity, increased *accidents*, more fuel consumption, and deterioration in air quality. Termination problems that include parking of vehicles at kerb and off street and loading and unloading goods at road –side; thus making *transportation planning* inevitable. The city of Freetown is politically divided into eight municipalities or wards. Our case study Freetown Centre One is a part of the affected transport sector of the city. Urban transportation problem are as old as cities (Pederson 1980), the total sum of all transportation problems is divided into those that relate to direct service problems such as congestion, inadequate capacity, and lack of safety for the user among others. The problems of transportation vary from place to place; the social and economic development in the human and the geographical space make traffic problems inevitable. Hence, the various types of transport problem generator make transportation planning inevitable and unavoidable. Generally, it is believed that the Urban Transportation Planning Process (UTPP) originated with the Chicago Area Transportation Study (CATS, 1959), in which traffic demands were forecasted based on the assumption that they were related to human travel behaviour, land use, and travel patterns. The UTPP has been the most popular tool for travel demand forecast in urban areas (Dickey, 1983). Papacostas and Prevedouros (2005) define UTPP as "to perform a conditional prediction of travel demand in order to estimate the likely transportation consequences of several transportation alternatives".

Modeling is an important part of any large-scale decision-making process in any system. *Travel demand* modeling aims to establish the spatial distribution of travel explicitly by means of an appropriate system of zones. Modeling of demand thus implies a procedure for predicting what travel decisions people would like to make given the generalized travel cost of each alternatives. The base decisions include the choice of destination, the choice of the

mode, and the choice of the route. The model starts with defining the study area and dividing them into a number of zones and considering the entire transport network in the system. The database also include the current (base year) levels of population, economic activity like employment, shopping space, educational, and leisure facilities of each zone. Then the *trip generation model* is evolved which uses the above data to estimate the total number of trips generated and attracted by each zone. (Mathew and Krishna Rao, 2007).
This study will focus on the trip generation model for the study area.

II. AIM AND OBJECTIVES

The Aim
The main aim of this study is to develop mathematical models, using the regression analysis technique that will clearly describe the relation between household structures, socio-economic characteristic and trip making ability.

Specific Objectives
The objectives of this study are to:

- develop mathematical models for household trip generation of Freetown Centre One, using the regression analysis technique.
- describe the relation between household structures, socio-economic characteristic and trip making ability.
- forecast future demand leading to transportation planning programmes for future development of the Freetown Centre One Community.

III. METHODOLOGY

Study Area: The research was conducted in Freetown Central 1 Community, which forms part of the geopolitical area of the Western Urban District of Sierra Leone. It also forms a larger portion of the Central Business District (CBD). It is of a typical urban setting and one of the largest areas in the Western Urban District, with an average population of 49370 (2004 Census-Centre Statistic Office) and the number of households within the community sum up to about 8806 (2004 Census-Centre Statistics Office).

Research Design: The design of this research is a descriptive research. The study was conducted to develop household trip generation models of Freetown Centre One by multiple regression analysis.

Population : The population of the study is the inhabitants of Freetown centre One district, ages 14 and above.

Sample Procedure and Sample size: The sampling method used is based on some form of random sampling, which entails the selection of units from the area of study. Simple random sampling technique is used to draw samples from the household population. Using Freetown Centre One population as many as 49370 and confidence level 3%, the minimum amount of samples required are 239. In this study the number was extended to 252 samples.

IV. INSTRUMENTATION AND DATA COLLECTION

The instruments used for this study were structured questionnaires. A typical working day was selected for the survey and the members of the household were asked about the details required in the questionnaire, through the head of the household. Care was taken so that each member (except for children below 14 years of the household) should answer about their own travel details, however this was done only per person per household. Since the actual survey may take place any time during the day, the respondents were required to answer the question about the travel details of the previous day. The questionnaire issued has three major sections; household characteristics, personal characteristics, and trip details. For this study two method of data collection techniques were used: Household Personal Interview Surveys and Household Self-Completion Surveys. The mode of communication for clarity and simplicity besides English language was predominantly Krio, which is being understood by almost every respondent. These actually help to reduce the category of selective bias so that accurate data were collected and the models to be developed will be a true representation of the study area. In this research, 252 questionnaires were used in the analysis of the data.

Data Analysis: The analysis is done with the help of SPSS (Statistical Package for the Social Sciences) software.

Results/Findings: This section presents an analysis of the findings. The responses have been interpreted carefully using tables and charts where necessary.

Results of Trip Data: This part of the survey aims at detecting and characterizing all trips made by any of the household members. A trip is normally defined as any movement greater than 300 meters from an origin to a destination with a given purpose. Trips are characterized on the basis of variables such as: origin and destination, trip purpose, trip start and ending times, mode used, etc.
The trip purposes were however categorized into three namely:

- Home based work purpose (HBW) – work trips that either begin or end at home
- Home based other purpose (HBO) – trips that either begin or end at home, that are not work, school or shopping related
- Non-home-based purpose (NHB) – trips that neither begin nor end at home

DEDUCTIONS FROM DISTRIBUTION OF TRIPS BY PURPOSE: Classification of trips according to its purpose is important to be carried out since people do travel for various reasons. In this research, among 508 trips generated by 252 surveyed households, most of the trips (319 trips, 63%) are Home based Other trip where either origin or destination of the trip maker is home. Home Based work and Non home-Based Other are as many as 149 and 40 or 29% and 8% of the total trips respectively. Complete results for trip purpose classification are shown in figure 1.

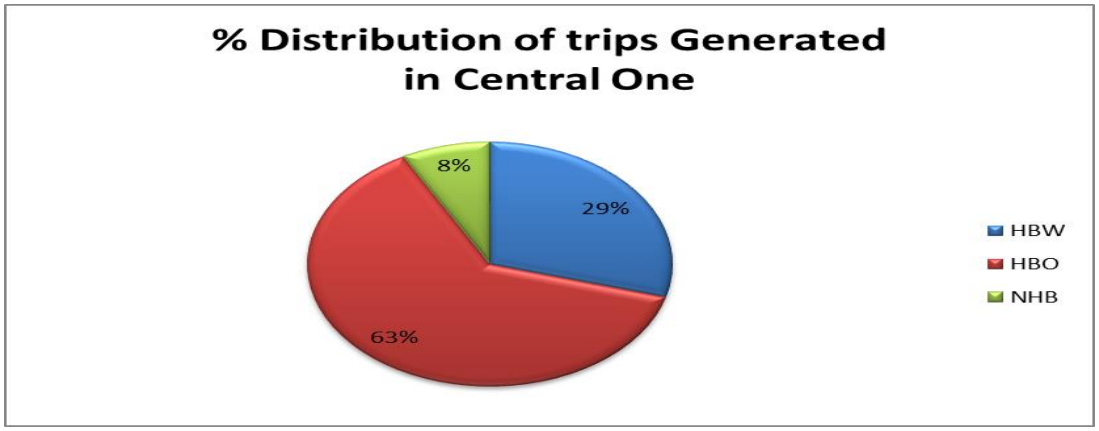

Fig. 1 Summary of Trips generated in Freetown Centre One

Deductions from Distribution of Trips by Purpose and Mode: It can be deduced from Figure 2 and Figure 3 that the major mode of trip is walk, followed by public transportation. This is due to the fact that the study area is part of the Centre Business District and commuters will decide to walk rather than join public transportation since there is a lot of traffic congestion. The lower mode of trip by private car is in agreement with the less auto ownership. However, one must not forget the significant percentage of mode by motor-cycle, which is now a growing mode of trip as a response to congestion especially during peak hours. Most people also return home from their work, business, school and other trips (visitation to hospitals, banks, recreations etc). Besides, people returning - home -other- purpose trip has higher percentage followed by work, trade and then education. The need for people to interchange trips in search of other activities or facilities is low as can be seen from the least percentage on change of transport.

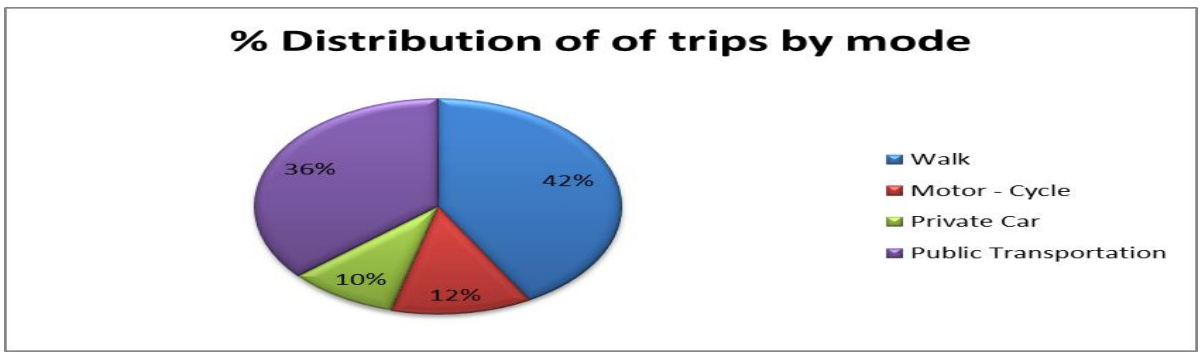

Fig. 2 Distribution of trips by mode of travel in Freetown Centre One

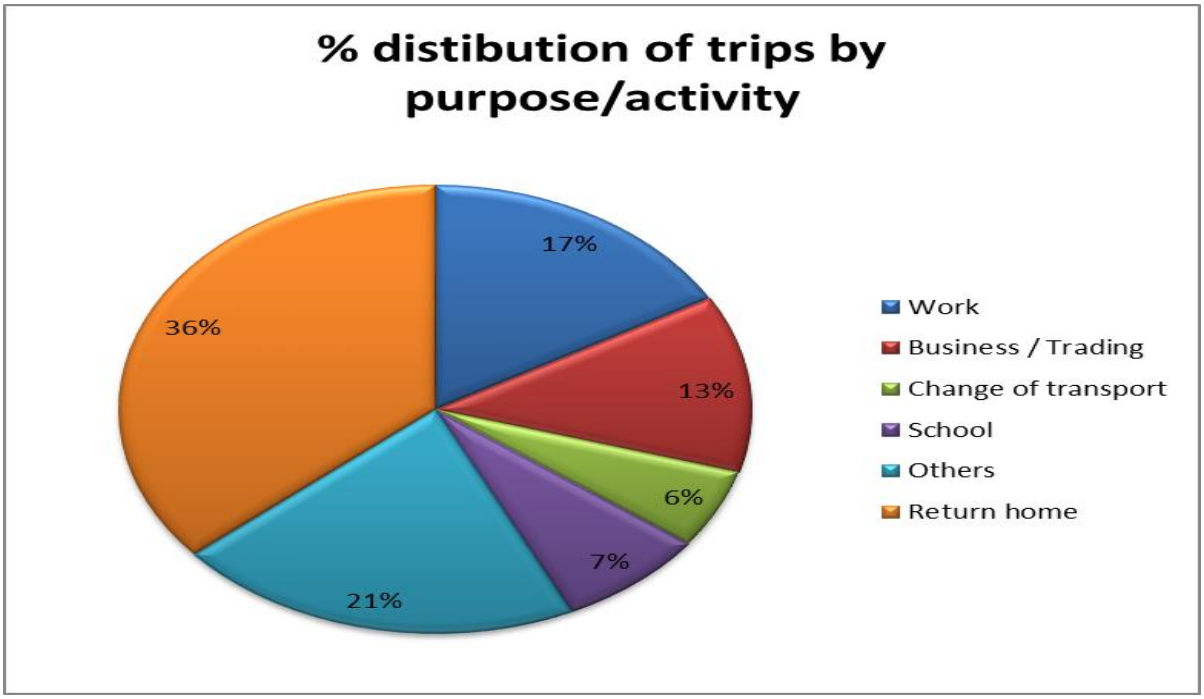

Fig. 3 Distribution of trips by purpose of travel in Freetown Centre One

Deduction from Distributions Of Number Of Households, Auto Mobile Availability And Trips By Family Size: It is observed from Figure 4 that the family size (6-10) has the highest number of household simultaneously with auto ownership. However, its number of trips is almost as family size (1-5) which is next in ranking. This shows that the number of trips per household increases for specific group of family sizes with increase in auto ownership. It can also be seen that the number of trips are higher than the number of households. This is because in most cases, for example one person can generate at least two trips a day (i.e. home to office, office to home; or home to shopping, shopping to home; home to school, school to home; home to recreation, recreation to home). Clearly the numbers of trips generated by households depend on the characteristics of the households.

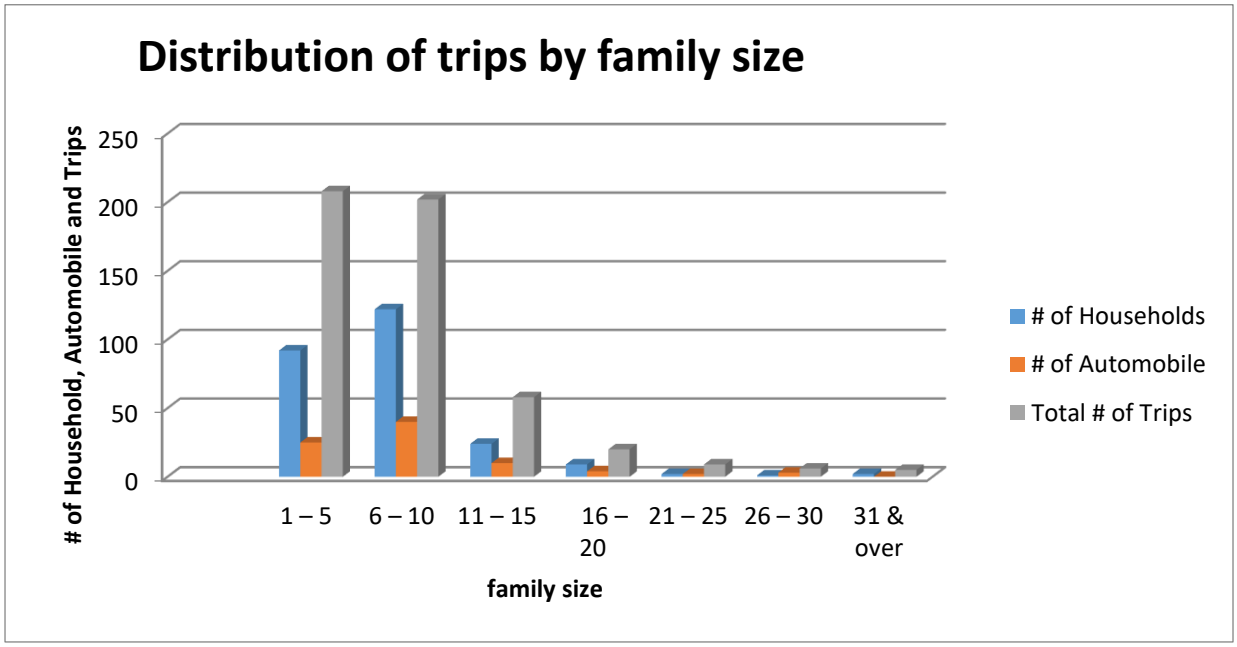

Figure 4. Distribution of trips by Family Size

DEDUCTION FROM DISTRIBUTIONS OF NUMBER OF HOUSEHOLDS, AUTO MOBILE AVAILABILITY AND TRIPS BY INCOME

The following can be deduced from Figure 5

1. Household with income size (10-14) million generate more trips though it has about 18% of auto mobile. This is because, almost every household of this income group can afford to travel.
2. Auto ownership increases steadily as the income levels increase. This may be due to the fact that most of those who choose to have automobiles work outside the study area (Freetown Centre One) and have enough money to secure one, while others choose not to do so as a result of low income. Also the study area has a host of facilities that influence trip generation from outside.
3. The number of household increases with increase in income up to level (10-14) million Leones and then decreases to income level (18&over). Those living in extreme higher income are almost as those in extreme lower income. This is typical of an urban settlement in underdeveloped countries.

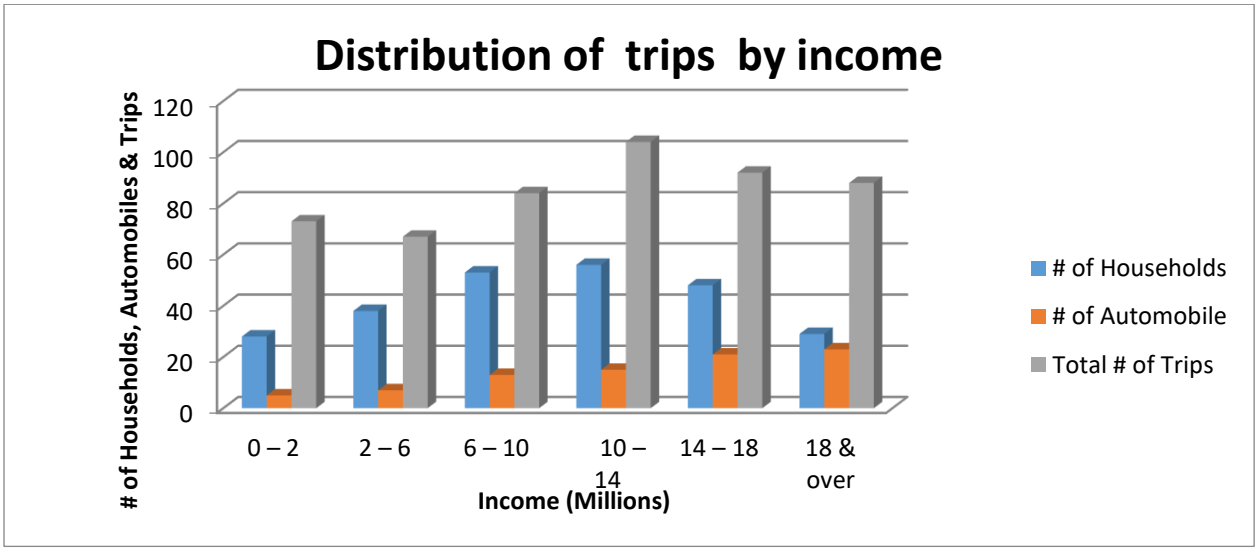

Fig. 5 Distribution of trips by family income.

TRIP GENERATION MODELS: Regression technique is a major statistical method that establishes relationship between one variable and one or more other variables. A developed equation using existing data, can be used to predict the dependent variable. The important features of this method include:

1. The equation derived is purely empirical in nature.
2. The method is based on the premise that the regression coefficients initially established will still remain unchanged in the future and can be used in the regression equation for predicting future travel.

For this research, the variations used in the analysis are defined as follows:

The independents and dependents variables are described in the following tables.

Table 1 Description of independents variables / Parameters used in the analysis

No.	Independent Variables	Symbol
1	Size of Households	X_1
2	Number of persons 14 years & over	X_2
3	Number of Male	X_3
4	Number of Female	X_4
5	Number of Worker	X_5
6	Number of Trader	X_6
7	Number of Student	X_7
8	Number of Auto mobile	X_8
9	Household income (per 1000)	X_9

Table 2 Description of dependents variables / Parameters used in the analysis

No.	Dependent Variables	Symbol
1	Home based work trips	Y_{HBW}
2	Home based other trips	Y_{HBO}
3	Non- Home based trips	Y_{HNB}
4	Total trips generated	Y_{TTG}

STEPWISE AND MULTIPLE REGRESSION ANALYSIS FOR TRIP GENERATION MODELS GENERATED : In running the regression analysis for Trip Generation Models generated, all the descriptors in Table 1 were entered at first and a stepwise and a multiply regression analyses were done. The results obtained give the proposed model for trip generation models generated as shown in table 3:

Table 3 Formulated Trip Generation Models

NO	MODEL TYPE	MODEL	R	R^2
1	Total Number of Household Trip Generation	$\mathbf{Y_{TTG} = 1.351 + 0.00004244X_9 + 0.126\ X_7}$	0.328	0.108
2	Total Number of Home Based Work Trips	$\mathbf{Y_{HBW} = 0.377 + 0.00001969X_9}$	0.165	0.027
3	Total Number of Home Based Other Trips	$\mathbf{Y_{HBO} = 1.091 + 0.108X_7}$	0.181	0.033
4	Total Number of Non Home Based Trips	$\mathbf{Y_{NHB} = 0.167 + 0.00000982X_9}$	0.232	0.054

V. DISCUSSIONS

The results of the analysis show that:

- People with higher income and more automobile availability make more trips than people with a lower income and less automobile availability, this finding is in agreement with that of Oyedepo and Makinde (2009). However, it was also discovered that because the study area is part of the Centre Business District, the most common mode of trip is walk, this is because commuters will decide to walk rather than join public transportation since there is a lot of traffic congestion and the study area is a host of many facilities that influence trip generation.
- Smaller family sizes generate more trips than those with larger family sizes; that is trip generation decreases with increase in family size for the study area.
- Home based other trip makes the largest percentage (63%) of people in Freetown Centre One (this is in agreement with the findings of of Oyedepo and Makinde (2009)); while home based work and non home base contributes 29% and 8% respectively.
- household income is the most significant parameter in estimating total trip generation, home based work, and home-based other trips, while the number of students influences only the non-home based other trip for Freetown Centre One.

Optimization of Model: In this project, model optimization was done only for household income. Since household income is the most significant predicator for trips generation, it was assumed that there exists another zone (within the city) with a similar structure as the study area but whose household income is slightly different. We therefore considered a zone with a 20% higher income level than the study area but with all other parameters remaining the same. The same sample size of 252 was used and variables used in this optimization have the same meaning as before. The multiple regression analysis was done for this new zone and the following results were obtained as in table 6.

Table 6 Summary of Results for Model Optimization

R	R^2	Adjusted R	$F_{computed}$	$F_{tabulated}$		Degree of Freedom	
				5%	1%	df_1	df_2
0.328	0.108	0.101	**15.04**	**3.03**	**4.69**	**2**	**249**

Comparing the R^2 values for this optimization (0.108) to the one initially obtained for the study area (0.108) one can see that they are the same. We can therefore conclude that the model developed for household trip generation is applicable to other zones with similar socio-economic characteristics as the study area. This also suggests that the model can still be useful if the income level of the people in the study area improves by 20%.

VI. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

It is concluded based on the findings:

- That household income is the most significant parameter in estimating total trip generation, home based work, and home based other trips, while the number of students influences only the non-home based other trip for Freetown Centre One.
- That the result of the regression analysis of total trips generated as dependent variable as against other variables such as size of households, number of persons aged 14 years & over, number of male and female, number of workers, traders, students, automobiles and household income gives value of R and R^2 as 32.8% (0.328) and 10.8% (0.108) respectively for the regression analysis of the socio-economic status of the people. R = 32.8% means that there is 32.8% linear relationship between the dependent and independent variables. R^2 = 10.8% means that 10.8% of the dependent variable is explained by the independent variables included in the regression analysis. Model validation and optimization were done to test the usefulness of the proposed models. These results confirm that the proposed models can be used to forecast future trip number for the study area and areas with similar household socioeconomic attributes.

Recommendations : The changes in land use pattern and the rapid growth of automobile ownership, especially motorcycle, have shifted the people's movement pattern. Thus, new planning should be conducted in order to create reliable and sustainable public transport system.

Parking of vehicles at kerb and off street and loading and unloading goods at road-side must be avoided, as this a major contribution to traffic congestion which has a significant impact on trip generation.

It might be expected that the opening up of a new road (Hill by Pass road) in the study area, by making new opportunities available, would have a considerable effect on the occupation of people in the area. As a result of this the developed model should be used to help predict the trip number and socioeconomics attributes.

There should be public enlightenment campaigns on laws, ordinances and regulations of traffic control devices such as traffic signs, signals and pavement marking.

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